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A View of Science Education
Review and Forecast

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Chapter I

INTRODUCTION

Why teach science? Perhaps the simplest answer to this question is to say that children and adults alike are interested and concerned with it. Science is around us everywhere, and teachers and students today are finding it increasingly difficult to keep abreast of current science. To add to the difficulty, more is being written in the field of science today than ever before. The daily headlines scream of new adventures into space, new accomplishments in the fields of medicine and chemistry, and challenging reports of our race in these areas with other nations of the world. Our children are no longer content to sit in a classroom reading of Galileo Galilei and Sir Isaac Newton when scientific breakthroughs have packed them with questions and ideas. Today's children are startling us with a curiosity indicative of a new level of sophistication born of this age of science. We accept this curiosity as good, and move forward with the knowledge that where interest and problems exist, learning evolves.

What has science to offer? A child's world is compounded of many things. It is a world of people, of buildings, of vehicles on the ground, in the air, and under and on the ocean. It is a world of changing textbooks, re-drawn maps, colorful conglomerations of travel to the moon, and voyages in atomic submarines. Attitudes and behaviors, beliefs and securities are shaken daily. The values of science in the child's world are tangible. These values are what justify the place of science in the educational pattern of today. Science, whether offered in the elementary school or at the secondary level, offers the student a *way of making sense* out of the chaos of the world. This may be called a method, a science method — but it is an *organized* method of discovering how things happen, and that in this wonderful world there are many reasons yet undiscovered by man. Dominant in a scientific method is a search for security, born of knowledge of cause and effect and making a pattern of predictability. The student gains confidence in his ability to solve problems only after he has solved a few. From knowing success in working out simple problems he grows in the reasonably secure confidence that he can solve more complex problems.

Creative powers of science. The creative powers of science must never be hidden by offering a narrow or one-sided curriculum in science education. The base of the curriculum must be broadened considerably especially at the elementary and junior high levels, so that a structured program at the secondary level will seek to habituate the scientific method as an attitude of mind and a natural way of life.

What are scientific methods? Usually the "steps" in the scientific method are patterned after the following:

1. There is a sense of perplexity, of want, or of being thwarted. The problem is then identified.
2. The tentative hypothesis or hypotheses occur. These may be based upon a supposed relationship between what is perplexing in the situation and what has been previously experienced.

3. The hypotheses are tested and elaborated upon and, in some cases, they may be supplemented by recourse to paper and pencil experiments or even more concrete practical experiments. Reference to books and other records may be necessary.

4. More rigorous tests are devised to which the resulting hypotheses may be subjected. Testing the hypotheses in these situations either solves the problem or reveals that the hypotheses do not stand the test of action.

5. A satisfactory solution is arrived at and acted upon. This may include devising a form of statement by means of which the conclusions may be expressed and communicated with the highest possible precision.

This is precisely the process of solving problems by thinking about them. (Thinking is the only process which affords a high probability of success in problem-solving. Problems are often solved by emotional reactions but the probability of the solution's being satisfactory is low.) Children and young adults share with mature scientists the ability to short-cut this step-by-step thinking. Very able thinkers often go directly to the solution once the problem has been clearly stated. In general, *if* a problem is clearly defined, it is well on the way to being solved in many cases. However, in teaching science, each step can be taught through specific activities. As an example, an entire class can subject to test the hypothesis that beans planted with the "eye" facing downward will grow faster than those planted with the "eye" facing upward. This means that thirty-five independent checks on the hypothesis can be made, with all sorts and conditions of light, moisture, soil composition, and temperature. There is no reason why pupils should not know the steps, see applications of each of them, and learn to take the steps one at a time.

Classification — a mode of problem-solving. Science uses classification of knowledges to a great extent. Categories such as biological science and physical science can further be broken down into chemistry, geology, astronomy, biology, and physics. Within these groups there are basic concepts called *principles* which state in declarative sentences that there are relationships among units of the real world and the forces that operate on these units. For example, the principle, "Sound is caused by vibrating matter," provides the label for a category, and envelope, or a "set" of relationships among all kinds of vibrating objects and a resulting disturbance which can be heard by normal ears. Always, all sounds can be traced to something which is vibrating. No sound is ever present unless something is vibrating. (Note that the statement of this principle is not reversible.) When a pupil seeks the source of any sound and can trace it to its vibrating source, when he cannot be dissuaded from this search by misdirection, clichés, superstitious beliefs, or someone's ignorance, *he has learned a little science.* When he also learns to write mathematical terms describing fully all sounds he is a scientist in the field of sound. If the pupil can handle many such principles with facility, and has a mastery of the relationships involved, he has an intellectual freedom and power which will allow him fearlessly to investigate that environment which is available to him from grade one through graduate school.

Problem-solving affords satisfaction. All of science is not classification or mathematical expression, but the appreciation of nature cannot be complete without knowledge of structure and relationships in nature. Learning the names of things is a very low level of learning, although it is necessary to know the exact labels for things so that science communication can be exact. Nevertheless, labels add little to understanding or appreciation of relationships. Yet the knowledge of the relationships among insects, plants, and man's food not only provides man with better bread, but it also gives him the satisfaction which arises from his having improved on nature! It is not an accident that a field of ripened grain under the sun and moving with the wind gives him also esthetic satisfaction.

Misconceptions cripple. Finally, the examination of misconceptions in science which cripple progress toward maturity is a kind of problem-solving also. No longer do small boys who wear glasses have to fight to maintain their integrity when called "four-eyes." Hearing aids are soon accepted by the group. Epilepsy still wrongly carries the stigma of supposed mental deterioration, and indeed the adult attitude towards mental illness will be changed only through years of scientific teaching about it in the schools. Misconceptions give rise to problem-solving situations. It is useless to tell the child that a misconception is not true. It must be *shown* to be fallacious by demonstration. Elementary science usually can do this. If a month's observation merely shows that smoke sometimes rises straight up before a storm, sometimes spreads along the ground, the old saying that "Smoke clings close to the ground before a storm" is not to be attacked. There are simply not enough data to make a judgment. This *delay in believing*, or *gentle skepticism* is a human trait that science education can and will foster. The only superstitious person is one who continues to act as if he believed in something which he, in fact, does not believe in.

Science teaching for all young people. Nothing that has been said so far has indicated that science is for scientists. It is indeed for everyone. There is room in the discipline for every kind of interest and every level of ability. There should not be any ceiling at any grade level on endeavor and achievement. The willing but untrained teacher can provide opportunities for teacher-pupil learning in science. Science teaching is not easy. It is almost impossible unless teachers will realize that it can be begun today, using the nearby environment, which is the child's world. It can be done, bit by bit, principle by principle, when the child has need of an expression which will tie together many things and forces about which he already knows a great deal on the cognitive level. Science teaching affords intense satisfaction to pupils and teachers. From knowing success in working out simple problems, pupils and teachers grow in confidence that they can solve more complex problems. This, then, is the way of growth.

Chapter II

TODAY'S PHILOSOPHY IN SCIENCE EDUCATION

Relating to conduct and new behaviors. Education is not merely an amassing of information. Neither is it necessarily the collecting of children and teachers in that new wonderful million-dollar school complete with green chalkboards and shiny tiled corridors. Our peripheral vision must be increased enough to realize that the most important ingredient in good education is still good teaching — not necessarily expansive curriculum, luxurious equipment, and good buildings. (We are not suggesting a return to Mark Hopkins and The Log, but neither are we agreeing that the education problem of today is merely one of real estate, to be overcome by building more schools and buying more books.) Learning can be sheer enjoyment if there is inspired teaching taking place. When learning *is* taking place, there is *good thinking* going on, and with good thinking come concomitant satisfactions of effective learning.

Aristotle believed that education was both easy and hard, and that it was not possible to master it fully, nor miss it wholly. He believed that each one of us adds a little to man's knowledge of nature, and from the accumulating of facts there arises grandeur. Aristotle, Plato, and a host of others had a tremendous faith in the youth of the nation. We could show our faith as teachers by insuring the desire of youth to experiment and explore while respecting the facts of the past, yet simultaneously submitting these facts to perpetual scrutiny. The education of children between the ages of 6 and 16 must be thoughtful, for this is the period when the spirit is either developed and matured or twisted and completely broken. It is these early years that etch the patterns for later years.

Education must show children how to apply their learning for use in the solution of life's problems; it must embue them with powers of patience, of concentration, and of good judgment. Real education, then, will be a reservoir of experience and knowledges together with a capacity to use them.

We hear daily about the urgent need for more trained scientists, more financial aid for science education, more science scholarships, yet the emphasis all seems to be on pouring these resources into the high schools and colleges. The vast area of growth, before high school training has begun, is dormant and ready for science training and intellectual probing. The skills in the three R's are begun in the grades, yet in science education, much learning that is scientific in nature is acquired only accidentally or incidentally. Washburn[1] says:

> "If we expect to improve the quality of our educational output — and I say *quality* advisedly, as I'm sure that none of us wants mere *volume* of intellectual mediocrity: we want *quality at all levels*, and a framework in which superior quality can be discovered early and helped to its full potential — if, as I say, we want to improve the quality of our graduates, then *we must start right at the beginning*. The much-publicized talent searches, which yield high-school and college scholarships to our most intelligent youngsters, are important,

[1] Bradford H. Washburn, "A Metropolitan Climate For Education", An Address given at the Boston College Citizen's Seminar, February 18, 1958, Boston, Mass., p. 67.

worthy programs. But what is being done about the nourishment and care of the intellectual fingerlings whom these searches expect to net after they're a foot long?"

We may say, then, that science has an important place in the elementary school life of the child only as it serves the boys and girls and the democratic world in which they live. By this we mean that there is no special place in the elementary school science program for science to be studied without considering two important criteria: first, that we are teaching children; second, what science is it that is best for the child?

The environment of childhood, a micro-climate for discovery. Children and science both are continually searching for interpretations of the environment and learning how to operate with it, or at least orient themselves to its forces. Because children start this dynamic interpretation of the environment from the cradle, they arrive at school with some knowledge of how they are put together and how the world reacts to them and they to the world. To be sure, some children bring with them to school at this early age misconceptions and attitudes of fear and disbelief, while others come prepared for learning and ready for development. Science learning-from-experience begins at birth and many adults — parents and teachers — are likely to overlook the significant learning that has gone on in the early years of a child's life. The school and the home both should provide a wide choice of experiences for children. These experiences should encompass both the physical and biological sciences, and should not be dependent upon words to express the concept involved.

Let us return to the question of what science education is best for the child. We realize that all education is a threefold responsibility of the family, then of the family and community, and finally of the family, community, and school. If the parents of our pupils, and the community generally, look upon the schools as a sort of massive baby-sitting service, then the results of such a service will not be worth much. Parents and community alike must be brought to the realization that learning does not all go on in the school. We are after a learning *climate*, a place where our children are surrounded by an atmosphere of adequate formal education, and where early interests are fostered and developed through well-planned programs leading on to secondary school and college. The more adequately our youngsters are permitted to sample the offered educational menu the better they will be prepared to make the decisions required of them in their later years. The key words, then, may be *intellectual exploration.* It may suffice here to ask ourselves the question, "What has happened to the native, uninhibited curiosity which we had when we were young?"

Lest we assume that all children have this native curiosity, let us recognize that it is indeed sadly true that some children display a passive attitude toward an attempt to have them interpret the environment. They may show no curiosity, or they may even refuse to take part in a contrived experience. We know that early in the child's life there are many variables in the child's behavior. Some of these variables may often be due to differences in emotional capacity. This emotional aspect has often been neglected in education. In this respect, Craig[2] says:

[2] Gerald S. Craig, *Science For the Elementary School Teacher*, Ginn and Co., Boston, Massachusetts, 1958, p. 12.

> "Science, although objective and realistic within itself, causes many-angled emotional impacts on society and on the individual. The emotions engendered by science are generally constructive and positive. As a matter of fact, science as an activity of man has had a most wholesome effect on his emotions and his ideals."

There are many ways in which science may be related to the emotions of man. There are feelings of appreciation of what one finds of beauty in the world, of new discoveries and applications of science. These emotions, usually positive, fill the learner with feelings of joy, wonder and fulfillment. There are, too, emotions that can be quite negative and engender feelings of horror, disgust, and insecurity. There is a need for recognizing these emotions and the role they play in helping the child face reality.

The sequence of action in teaching is often in the following pattern. Facts are learned in an atmosphere of discovering relationships. These environmental relationships take on meanings which affect conduct at the moment of acting, and repeated acts establish a consistent behavior. Behaviors are ready for use in the solution of problems, which in turn involve new facts and relationships. How does a new experience in science, then, start this sequence of actions? In a fifth-grade classroom there is an experience in electricity being enjoyed by the pupils. An electric bell is connected to a push button and a dry cell. Insulated copper wire, bared at the connecting points, is used. The bell rings when the push button is pressed and a problem has been solved. The successful operator need not ask the teacher or adult about the correctness of the solution. Now if he is confronted with an alternating-current chime in his home which fails to sound its musical note when the front door button is pressed, but *does* announce an arrival at the back door, he will attempt to trace the wiring and find *similar* electronic connections to those he used in school. In this case, he may not always be successful, and will certainly see that there is no dry cell. Instead he will find a small metal-and-wire device near the fuse box, and he may have to seek more information from a book or an adult. He may even decide to clean and reconnect all the wires available to him, and so discover that the push button will come apart. As a matter of fact, he will most likely find that in the push button there is NOT a good clean path for electricity to follow, a fact he learned in school by cleaning insulation from the ends of his wire. Now he shines the push button contacts, reconnects the system and the front door bell rings!

His probing and thinking have demonstrated that circumstances with which he worked at school are very like those at home. He has established that there is a *set* of occurrences which are related. A learned behavior is effective for the solution of problems with similar elements. Now, not only will these problems be facile of solution, but there have been engendered new attitudes and appreciations. These are directed toward a method of science which has been taught and successfully used. These attitudes and appreciations can have far-reaching significances which a child might think of as: "I like to do things in science. I like it when I find two things that are almost alike so I can tell how the second one will work or how I can fix it. I can find out *for myself*. My mother and father will be pleased that I fixed the front door bell. They will be pleased that I learned how to do this in school. My teacher will let me tell the rest of the class what I did. Maybe I can be an electrician or an inventor when I grow up."

If the reader thinks that these attitudes and appreciations are very numerous and complex to ascribe to one small bit of science instruction he is right. Not all of these will come from one experience, but in time, a multitude of science experiences will provide every one of them. *Every* experience contributes something positive. In the academic part of the school curriculum, science alone gives much opportunity for involvement in the kinds of real experiences which alone can produce these attitudes and appreciations.

Transfer a reality in science education. Whatever theory of learning is subscribed to, real or vicarious experiences including introspective experiences, are the data at the base of conceptual thought. The child's environment encompasses him as the ocean supports its dwellers. He is immersed in it physically, intellectually, and emotionally. It is an immediate, a nearby thing; timely, relevant, pertinent, no matter what the problem is now or will be at school or home or at work. No bit of information, no relationship, no classification learned will be wasted. Time and again the unit or the process will be the key to unlocking the mystery of a new event. The environment will provide limitless opportunities for transfer. Still, there is a problem of how soon this environment will provide the opportunity. Such questions can be answered only by value judgments made by groups of individuals. Nevertheless, if younger children accept as their own the problems of their environment, whether posed by that environment directly or contrived by the teacher who can see a little further into the future than can the child, the likelihood of transfer of the specific and general elements of science is high. When elements of learning can also be back-lighted as by a flash of lightning through experiments and demonstrations by, with, or for children, they are highly likely to be retained. They have an elemental nature; they are fragmented-life; they are hot or cold, blue or golden, slippery or sweet. If the teacher will dignify this world of the child by making it part of the classroom, then the child may feel that he has a reciprocal obligation to be interested in the school's interests. A new climate of affection between teacher and pupil *can* result. The transfer of educational *attitudes* from science to all of school activities *can* result in better thinking and better knowledges. It is possible for science education to care for both the slow and the able. It can challenge both groups; every day children can be asked to do more than they possibly can.

The pupil who has no special abilities or interests is not forgotten. He is encouraged to be himself, and if that self does not fit into the standard mold, then perhaps we should allow him to retain his own mold, or at least keep the differences which set him apart from the others. All youth will not be the same. From energy-level to environmental background, the differences among the youth we are teaching are evident. Let us not reward conformity and place a premium on the student described as the All-American Boy! Let us instead, appreciate differences and look to the unusual for originality and creativeness.

Chapter III

SCIENCE IN THE ELEMENTARY SCHOOL

PEARL ASTRID NELSON

How children learn science. It is generally acknowledged that work in the school of today goes beyond the bounds of any textbook or any classroom. Teachers and children alike are more widely informed than ever before. This is indeed an age where new and timely topics can become a part of the elementary school curriculum because teachers have become expert welders and have learned how to join the old with the new and to follow competently the various avenues of knowledge which look promising for the scientific education of the young. Gone are the days when elementary school science was a mixture of religious philosophy and nature study, or a melding of scientific principles and memorization. Although teachers now look upon the entire school experience as designed to orient the child to the world, science in the grade school has achieved dignity as an integral part of the curriculum and is no longer considered a stepchild of the social studies area or an often-neglected part of the reading program. Children learn that facts are aids to help them get answers for things they want to know and from the learning of facts in this respect, they may explore what lies ahead. Subject matter is taught so that one field of knowledge enriches others. Thus it is that science *thinking* is one of the major components of the learning that goes on daily in the classroom.

Class discussions. How do children learn to think in science? One of the most important techniques used today, whether at the primary or upper level, is that of class discussion. The "whys" are explored thoroughly by this method, which is especially effective when used by teachers who are expert in the "hands-off" policy for growing minds. Interpretations of materials read are begun at an early age, and the young are taught to study current literature critically. This is accomplished in many ways. In the primary grades, the morning "share and tell" period is used for this purpose quite widely, and in the intermediate and upper grades, interpretations are made during panel discussions, debates and group conversations. Variety of opinions have been explored and misconceptions avoided at the start.

The elementary school child learns by intellectual *doing.* As far as possible, he is taught kinaesthetically, and all avenues of approach are opened for him. Sounds, sights, and smells — these all stir the child's five senses. So it is, then, that the child may learn more about electricity when he has "tasted" it from a constructed lemon cell or from a wired dry cell; he may learn to know the difference between poison sumac and the non-poisonous variety by using his eyes during a field trip, and he may learn to distinguish a robbin's call from that of a flicker by using a bird-call recording prior to a bird walk, or even in lieu of one. Often it is necessary to train the senses to become a little keener. In this respect children should be given practice in using their senses to gather information, in arriving at tentative explanations based upon their findings and in checking their explanations. Such is the beginning of the scientific method. When can this be started? Teachers at the pre-school kindergarten level of teaching are especially adept at this training of the senses. For example, a series of paper bags may be

filled with raisins, popcorn, peanuts, gumdrops, jelly beans, marshmallows, etc., and the children asked to guess what is inside each bag. The bags are closed by a rubber band slipped around the top, and the children are first allowed to guess each bag's contents by "jumping to conclusions." Then a second judgment is given when the child is asked to *smell* the contents of the bag with his eyes closed. Later, *feeling*, *listening*, *weighing*, and *looking* are all used as methods for establishing hypotheses.

If the children are to acquire the art of sound thinking, they must receive this experience in every subject and not in science alone. It is sad to think that science has been over-emphasized as the one subject area in the curriculum where "scientific thinking" is to be done. It is most important that a staunch scientific attitude pervade the teaching of all subject matter, from social studies to physical education. There will be some transfer of scientific thinking from the science lesson to other instructions, but only if the teacher consciously does this.

What about this matter of correlation? We have said that science need not be subject to a pseudo-type of integration, but may stand with dignity either alone or as an inclusive part of the curriculum. Hanley and Schiesser[1] say in this regard:

> "No school subject offers more opportunities for integration than science, except, perhaps, the language arts. Science can be related to history through industrial development, transportation, and medical achievement; to geography through maps, agriculture, industry, and geology. The scientific methods of problems solving are needed in all phases of the social studies. Science relates to physical education through mechanics, ballistics, and physiology. Science relates to art through color and space. It relates to music through sound, construction of musical instruments, and concepts of time. Science is an ideal stimulant for reference-type reading and for oral and written language work. It can contribute to arithmetic readiness by encouraging children to measure, weigh, count, compare, and clock."

There is one danger that educators in general must constantly be aware of in regard to science in the elementary school. That is, in brief, that science not become a "catch-all" for many other subjects: health, physical education, safety, or conservation. Although it is possible to integrate the science program with the social studies program in most instances, it is often a wise choice on the part of the teacher to engage in a pure science project or unit, for the sake of science itself, and not always consider the social studies theme as the more prominent one. This is true at all levels of the elementary school, and not merely at the primary grades.

Although the science program must not be centered solely on the interests of the child, it is recommended that in planning what to teach in science, the teacher plan a program which will be at the level of the class she is teaching, satisfy the questions and needs of her class, and be a part

[1] George H. Hanley and Evelyn Schiesser, "A Point of View for Science," *Science for Today's Children*, the Thirty-Second Yearbook, National Elementary Principal, National Education Association, Washington, D. C. (September 1953), pp. 19–20.

of the total program she is teaching at the time. Hanor Webb,[2] professor at George Peabody College speaks of nine reasons why science is taught in today's elementary schools:

1. To give practice in simple observations — as background for future investigation and understanding of the environment.
2. To give practice in purposeful activity — as background for future experimentation and constructive labor.
3. To give experience in combining the factual and the emotional (as caring for a well-loved pet or flower) as background for future appreciation of natural beauty and law.
4. To enlarge the vocabulary with the names of simple objects and processes — as background for the future use of necessary technical terms.
5. To guide emotional responses away from the highly subjective and toward the objective — as background for future sensible attitudes and desirable behavior.
6. To start habits of scientific thinking in simple matters — as background for scientific thinking in important future decisions.
7. To start building attitudes toward the simple social effects of science — as background for future cooperation in community programs of health and welfare.
8. To develop simple concepts such as cause and effect, balance of nature, cycles of nature, and the like — as background for future understanding of broad concepts like conservation of resources, the laws of learning, and even the sacredness of truth.
9. To develop a simple reverence for nature — as background for future appreciation of the wisdom and power of God.

Necessity for a structured program. Today there is an evident need for a definite structured program in elementary school science. A structured program may be defined as one where definite areas in science are studied. This is in direct contrast with the accidental and incidental program of the past. In the latter, if Johnny brought his steam-engine to school, the forms of matter could be studied, but if Johnny did not lug his toy to class, then liquids and solids were never investigated. While incidental science is sometimes very effective, it cannot be relied upon to provide a well-rounded, *structured* program for the young child. Of course, the program needs to provide for incidental or current learnings that are important, but the planned experiences, the planned units of work are the bases for an adequate program.

[2] Hanor A. Webb, "Nine Reasons Why," *Science For Today's Children*, the Thirty-Second Yearbook, National Elementary Principal, National Education Association, Washington, D. C. (September 1953), p. 22.

Research indicates that there are no *areas* which are best covered at specific grade levels, but within the numerous areas are experiments and experiences which have been ascertained as being more appropriate for a given grade. For example, although magnetism and static electricity may well be studied at the primary level, there exist classic experiments involving permanent magnetic fields and electro-plating which are more understandable at the upper elementary level. It is wise to keep in mind that many of these experiences considered too difficult for the average pupil in the lower grades may well be used in the enriched program in science for the bright and gifted. Some school systems, alert to the situation of repetition of science areas throughout the grades — which may result in boredom for the child — have, with the aid of consultants and functioning science committees, evolved a program where specific *areas* are designated for different grades, with at least one repetition at a different grade level. Thus, a child may study simple geology in the second grade, classifying rocks and mineral specimens by color and luster and, later, engage in a study of this type at the sixth grade level in relation to his study of old world backgrounds, primitive man, volcanoes, and the changing surface of the earth. On this higher level, he would learn to classify rock specimens into three main categories, and investigate Moh's Scale. This system, entailing two experiences in the chosen area, is proving satisfactory for those schools experimenting with it, and appears to be one step ahead of the usual study-guide or course of study where teachers may choose their own science areas at will. The difficulties with the latter systems are evident. The writer would like to see tried a yearly science "theme" in a particular elementary school. In this respect, the teachers would work with their classes at different levels on one general theme for the year, such as *Weather, How It Affects Us In Our Daily Living*. The wide spread of activities and experiences from Kindergarten through Grade Six should prove very interesting and enlightening.

Books, materials, and apparatus. Elementary school pupils become quickly familiar with the basic tools of science. Although teachers have always been versatile in the making and using of homemade science equipment, in part, due to school economy of the past, they have been adjusted to doing without many tools and materials. There are, however, basic materials which are necessary for the functioning of any well-run science program. This does not mean that good science teaching is dependent upon commercial materials, but it is evident that the best programs are the result of good teaching plus adequate books and supplies. If we accept the fact that good elementary science is *doing* something, then we agree that pupils need to master skills as well as knowledge. The skill in science may only be mastered by using the material in the field. Skill is not verbal and cannot be mastered by discussions. Thus it is that laboratory techniques aid in the development of skills. The young child *makes* an aquarium; he observes the insect's wing under a *hand* lens; he watches the development of mold in a *petri-dish;* and plunges the *tuning fork* into water to learn that sound is caused by vibration. It is obvious that active investigation is one of the most promising methods of teaching children science. This includes the gamut from reading the thermometer in grade one to a research study of water pollution in grade six. A special form of this technique is the use of field trips and interviews. The trips to the farm and to the fire station are not new, and certainly if they are not a part of some larger under-

taking, they have only partial value. Thus, a trip to a local quarry has significance only if simple geology and the changing surface of the earth is being studied. Most communities offer almost inexhaustible supplies of individuals and groups which may be called upon to enrich the science life of the child. School camping is not new, and the idea which originated in the schools of New York, Michigan, Pennsylvania and the West Coast has slowly spread to the East Coast, where many school children enjoy the experience of living together in a camping situation for a week or longer.

Equipment: Another essential to the teaching of elementary school science is audio-visual material. A program-in-action requires the use of projectors, record players, radios, and tape-recorders. Needless to say, plenty of time for pre-teaching and post-teaching activities relative to audio-visual materials is of the utmost importance.

There are numerous science kits on the market at the present time, with prices not too different from one another. Another similarity in common is that the kits all emphasize physical science rather than biological study. Each kit contains a variety of simple electrical, chemical, and optical items which may also be purchased separately at scientific supply houses. Whether or not the school provides such a kit or kits for the teachers, the material therein must always be supplemented by local and current needs of the particular classroom. Materials may be obtained in surprising variety from local hardware stores, pharmacies, groceries and garden shops. Children often bring into school construction items from Erector sets and Tinker Toy sets. Old skates, wagon wheels, kitchen devices, etc. may also be considered as less obvious but desirable materials.

The "science corner," a "must" in every classroom, may range all the way from orange crates to elaborate tables with marble or formica tops. The planning of such a corner will prove to be a valuable experience to the children, for it is in group activities such as this that the child learns responsibility and the spirit of working together. In this day of crowded classrooms, the elementary teacher may understandably wail, "A corner for science! I have only four corners in my room and they're all taken up with a library corner, an art corner, a music corner and a workbench!" Perhaps the answer to her predicament is to advise her to "take science out of the corner and put it in the middle of the room!"

The use of science books is a necessity in our modern age. However, learning to use science books wisely as a resource in the development of children will pay off greatly in the way of personal satisfaction of the teacher when she realizes that her young charges are using, not abusing, books. Science texts and trade books can help teachers teach science and children learn science. They can open up new areas for study and vitalize and motivate the instruction at all phases. In regard to science books, Craig[3] says: "Science books, with the accompanying teachers manuals, can assist the teacher to be adequate for the problems of teaching science. In fact, a teacher can feel quite secure in that children can turn to the *books* for content rather than using her as an information bureau." Reading in science should not be rapid reading, but rather reading with thinking as the main purpose. Science books do not constitute another reading book, or even another reading program. Reading in or from science books should

[3] Gerald S. Craig, *Science for the Elementary School Teacher*, New Edition, Ginn and Company, Boston, Mass., 1958, p. 137.

always be in search of answers to questions and should be accompanied by discussions, experiments, recording of information and other activities. Rarely should every child have a book of the same type in his hand and rarely should there be continuous reading for long periods of time. Usually, science books are used co-operatively by the teacher and the pupil, and should always provide for a pleasant and stimulating experience. While the teacher is learning from the science books, she is also continuously studying the behavior of the children and observing how they are thinking and learning. In science reading especially, are frequent stops necessary. These stops are for emphasis, for considering what has been read, and for discussion of the material covered.

The science vocabulary. Some attention should be given to the building of the science vocabulary. Whether the new words learned be incorporated in the regular vocabulary listing, or whether the words are placed in a particular list of science words is up to the discretion of the teacher and the grade. It is well to encourage the use of the words in *all* experiences so that they will become charged with meaning and become an active part of the vocabulary of the child and not be limited to his science reading or speaking. In regard to science words, the writer[4] states:

> "Psychologists and educators in general have accepted the idea that some words are more highly 'charged' than others. Public speakers have purposely injected these highly significant words into their lectures for the purpose of obtaining the attention of the audience especially during the occasion of a dull or overly long speech. These electric words or phrases may have to do with sex, politics, religion, race, or country, yet they are immediate attention-getters and the sleepiest audience in the world will respond to interjections of words of this type. We must use attention-getters in education. In science, especially, are we anxious to know methods of charging words with significance and meaning. It is possible that many scientific concepts and understandings hitherto not considered suitable for children of elementary school, may become fitting, necessary and pertinent if they are charged with drama, excitement and pertinence before they are used as part of the commonplace vocabulary in the classroom."

During the past ten years radio and television have come into our lives. Although teaching science by means of television to the elementary school child is still in the experimental stage, it is evident that the use of television is not supplanting the role of the teacher, but making the work of the teacher more important than ever. The more numerous the sources of information, the more important the role of the teacher becomes.

Physical and biological science. What kinds of science should be taught in the elementary school? The writer feels that the elementary school is no place for phases or highlights of the subject. Certainly a single area such as insect-life or shell-collecting is not to be thought of as constituting a course of study; neither is a warped science program where biological science is taught to the exclusion of the physical sciences. The physical

[4] Pearl Astrid Nelson, "Super Chargers for Elementary School Science Vocabulary." *School Science and Mathematics* (May 1958), p. 354.

sciences are as important to the child of today as the study of nature was to the child of yesterday. This does not infer that the biological sciences are to be forgotten. A happy balance needs to be obtained in this respect, with a 70–30 balance in favor of physical science being maintained at the intermediate and upper grade level, and a 40–60 ratio at the kindergarten and primary levels. In this respect, Cooper says:[5]

> "Rocks are just as much a part of the child's environment as plants and animals. He needs to understand rocks, too. Meteorology and the forces of air in motion should come in for as much consideration as other phases of science in building the elementary school curriculum. Astronomy and geology are a part of the environment of all and must be given their share of attention if the child is to be at home in his world of moon and stars, plains and mountains. To stress one of two areas of the great field of science in the elementary-school curriculum and leave out the other important areas is to 'miss the boat' in this great opportunity for learning."

We are not trying to make a scientist out of the child in the grade school. He may develop into a physicist or an astronomer at a later time in his life, perhaps, because of his early interests in the subject. Our big objective is to help him adjust to his environment by giving him many experiences with science and science materials.

Evaluation trends. Science is an interrelated body of knowledge capable of testing. However, it should be remembered that the level of understanding of the principal ideas in science and their applications to daily living will be different from that of the pupil in the secondary school. The difference will be in part, due to overlap in terms of individual interests in science and individual differences in ability. The teacher of little children will constantly ask herself if her class has acquired and retained useful science facts; if they have a workable understanding of science principles; if they have learned methods in attacking problems; and, finally, if they have reached a level of inderstanding and performance which is commensurate with their ability. How may the teacher test the validity of these criteria? First, she may keep anecdotal records of the ways in which children use scientific thinking in attacking science problems. This is one of the most important ways in which we learn how children think in science — as well as in other subjects. The type of test she writes during a unit or at the end of a project may describe real-life problem situations which provide her with the opportunity of appraising the child's understanding of the principles of science. Tests of facts include regular objective tests, the difficulty and construction depending upon the age and grade of the child.

Objective testing may not be confined to testing factual information only. There should be a constant sampling of the *understanding* of the big idea of science. Such test items that require two answers, one factual and one requiring understanding are particularly desirable at the upper grade level. Games involving matching or "partnering" are particularly functional at the intermediate grade level. The writer[6] devised a type of test

[5] Norman C. Cooper, "Unit Concepts in Elementary-School Science," *Science For Today's Children*, the Thirty-Second Yearbook, National Elementary Principal, National Education Association (September 1953), p. 146.

[6] Pearl Astrid Nelson, "The Acquisition of Concepts of Light and Sound in the Intermediate Grades," *Science Education* (October 1958), 42: pp. 356–361.

for the purpose of making science analogies in the areas of *light* and *sound*. These tests were called Object Classification Tests. The child was asked to make pairs of science models and then tell why he placed the particular items together. If the child gave a perfect response for the test he was given a score of two, and if he evidenced some idea or partial concept for the proper analogue he received a score of one. For example, in the area of *sound*, the models that the child was asked to classify were the following: Tonnette and recorder; horn and reed; bat and dog whistle; ear muffs and insulation; toy telephone and stethescope; violin bow and carpenter's file; sea shell and gallon jug. Although there were naturally many answers and ideas expressed, the study of the individual scores certainly provided the teacher with diagnostic information as to the child's science progress. These models may also be used individually as well as in pairs for problem-solving situations and for investigations into kinds of thinking.

Types of behavior may be used by the teacher as an evaluation technique, one of the most important being that of the children's expression of ideas. Oral reporting should be used, with the teacher keeping in mind constantly that some children will need more help than others in this respect. There is always a danger in over-using written work as a form of evaluation. It is very easy to destroy interest in science by excessive use of laboratory sheets and notebook work in the upper grades. The keeping of records is very important and may be started at the primary level. A simple story or chart dictated by the pupils and constructed by the teacher in the first grade announces to the class that on October 3 a particular plant was placed in a dark closet, and that daily observations in this respect show finally that plants require water and sunshine. Records in which many children participate are feasible, such as the records that a weather committee might keep. Particularly at the primary grade level, science evaluation often may take the form of expression in art, such as large mural-work or drawings. Often misconceptions are discovered this way. The writer remembers her first class in second-grade science very well, in this respect, when a little girl attempted a draw a "Christmas *seal*" (the tuberculosis stamp) on a mural depicting Eskimo life!

Finally, let us not forget that evaluation is not an end in itself. In this respect Craig[7] says:

> "In considering evaluation teachers must recognize that there are many educational agencies — the home, television, movies, comic books, playmates, etc. Sometimes these agencies have desirable effects and sometimes not. The classroom teacher, as the official representative of democracy in the education of the children in her classroom must make certain that the total or aggregate influence on the lives of the children is beneficial. This is a large and important task. It is difficult to think of any service of greater social value to the children of a nation and of the world than this."

We can evaluate adequately if we keep constantly in mind the criteria of education in the elementary school and keep developing and improving new techniques in the field. When we probe these educational criteria and find that we are accomplishing our goals, then we may turn our sights to bigger and better methods in teaching science and in evaluating the results.

[7] Craig, *op. cit.*, p. 869.

Chapter IV

SCIENCE IN THE SECONDARY SCHOOL

JOHN G. READ

Science for all: A complex and expanding subject-matter base in science demands a definite sequence and a reasonably permanent educational organization. At the end of twelve or fourteen years of school a pupil should have had intellectual contact with every science area. The depth of penetration into these areas will range from appreciation to pure mathematics.

There are at least three types of organization for teaching science. Each is useful; none is exclusively suitable. Even the outcomes are not as crisp as the following discussion would seem to make them, for teachers and pupils will get from them much more than is planned.

1. The social studies centered unit examines a period in man's history, and shows the place of science in that framework. "Pioneer Life in New England," "The Problem of World Food Supplies," and "Automation and Wages" are ascending units which require a good deal of understanding of pure science if they are to be comprehensible. It is usually supposed that by formal or incidental teaching many of the basic science principles will have been learned. This may not be true. For instance, the well-sweep made of a forked and a straight branch is incomprehensible unless it is known that the women drew the water. This device was arranged so that they would not need to reach over the well and pull up the bucket, a chore that meant nothing to men with their different musculature. Nor will the utopia of a world in which no one will go to bed hungry be a realistic goal, which some one of the little girls sitting in the third row may make attainable, unless someone starts her on the study of plant genetics and hybrid grains long before she goes to college. In the twelfth-grade unit "Automation and Wages," sophistication in the field of economics must be matched by an understanding of systems research, of quality control, and a knowledge of the binary system and its utilization. There is need for something more than incidental science. One solution, often suggested, is to use suitable administrative devices in order that whatever science is needed to understand the social and economic problems of automation can be taught concurrently. The basic structure of science does not allow this. It is sequential, progressing from first environmental contacts of the young child until such sophistication is reached that practically *any* occurrence in his adult environment falls easily, almost automatically, into an envelope of correlates, which envelope is described by a principle. In connection with automation, consider the concept, "Low voltage electric currents move over complete circuits, and if an air gap is placed in the circuit, current will not flow." This concept, easily learned earlier, is exemplified in the operation of the computer whose relays are open (the binary symbol *zero*) or closed (the binary symbol *one*). The instance is trivial, but the reader can select any more complex operation in all of industry, communications, or in the field of health, and trace back high-level essential meanings to uncomplicated first learnings of science principles.

2. The natural history stage of inquiry is characterized by direct examination or apprehension of objects. Accurate observation, careful description, and the classification of objects are not only the means but are often the ends of this type of science. It should be said that there are concomitant learnings, many of which might result in the discovery of relationships, but the relationships are not always sought nor valued highly. The classic biology course is largely of this type. A block called "Human Physiology" is broken down into the systems; circulatory, nervous, reproductive and others. Also, there is a block called simply "Crustacea — a class of Arthropoda." In physics, perhaps the nearest equivalent might be named "The Particles of the Nucleus." It is likely that most of science taught today in the secondary school is of this natural history type. It is easily organized in the logical rather than in the difficult pyschological form to be described presently. It lends itself to precise evaluation, using objectively scorable matching, true-false, or completion items. Large quantities of facts and labels can be accumulated and a feeling of having accomplished a great deal gives teachers and pupils a sense of satisfaction which is close to repletion. There is little teaching invention needed beyond the mnemonic-device level or the "good study habits" indoctrination. But let there not be any bitterness creep into the discussion of the natural history type of science. The gains in special vocabulary for better communication are great. Every bit of better science teaching rests on natural history foundations, but the time to do the laying up of the stones is just before the building is raised and seen as a whole, else the wind and rain of time will destroy the whole elaborate base.

3. The third methodology of science-teaching used for organizing the real world is close to that by which most human learning takes place: the way of human thought. It is the method of teaching for the planned acquisition of concepts. It is not exclusively *the* method for science teaching. It is not a *substitute* for science teaching at its present best. It is a psychological rather than a logical approach. It has as its base the (written) verbally-expressed principle of science which is an evident relationship between or among real experiences of the environment. These principles are to be learned. "Learned" is taken to mean that the pupil can use the principle operationally to solve problems of the environment, first by classification, eventually by rewriting the principle as a mathematical formula. This description assumes that most of the problems of the environment will resolve themselves into the placing of the occurrences in the sets to which they belong. This will be done in the face of, actual or contrived (attractive and misleading), distractors. The structure of the method is based, most recently, on Northrop's *deductively formulated concepts*[1], of which these science principles are examples. Of these principles as deductively formulated concepts Albert Einstein said that they are not "given empirically, but are free inventions of the human intellect." They are also tools for interpreting future experiences, and through them may come invention, the only other mode of advancement in science.

Perhaps the best way to use the principle is as an exoskeleton for any desired organization of teaching science, including variations on the first two methods considered above. This means that whatever stage of science

[1] F. S. Northrup, *The Logic of the Sciences and the Humanities*, Macmillan Company, N. Y., 1948.

teaching a school or community is presently employing, a careful analysis will reveal that many basic principles are, in fact, being touched upon. When they appear as "explanations" for the first time, grade-wise, there is what amounts to a thalamic pause while the class abandons its progress toward whatever goals, and stops and sees clearly the unifying power of the principle. All previous experiences prehended are related to the presently apprehended occurrence, and the immediate future (of wider scope and deeper sophistication) which is subsumed under the principle is brought into the envelope. The operational process is psychologically sound, and a significant part of science teaching is now going on. The *coming* need for understanding the principle has a greater significance for the present need. Each use of the principle reinforces its learning. The stage is ready for the future when a new member of the class of occurrences which is described by the principle will appear. This new occurrence will be recognized at once as a member of the cast, and the action will further define the theme. Enough plays, and the real world will have been described. Its relationships with man are the plots of the history of science.

Pupil maturity: Lest it seem that science teaching is to be reduced to a type of Baconian enumeration, it should be realized that *maturity* is the key to sophistication in science. The long deep look at the part which science plays in human relationships after pupil maturation has first provided enough specific experiences so that making choices as to what occurrence constitutes a member of what set, poses a problem capable of solution; and second, when the school, through all its fragmented teaching, has used the wide-ranging interests of pupils to make meaningful and possible of interpretation the pressing social problems of our times.

The maturity of pupils must be matched by the maturity of the problems they see as their own.

The good science teacher: A good science teacher in a good science classroom is a composite of materials and activities which can be recognized as teacher and pupils are seen at work. Here are some observable characteristics:[2]

— There is a written list of the facts, understandings, skills, attitudes, appreciations and new behaviors which are joint goals of pupils and the teacher. Each major block of studies for the whole year will reiterate the long-range goals, and will have its own specifics which can be evaluated during and at the end of the block.

— Check-lists, designs for anecdotal recording, written objective tests, and a skeleton copy of the final examination are being constructed after the first few weeks of a semester.

— Pupils have in their possession a guide sheet which contains specific directions for engaging in activities which will forward progress toward reaching jointly arrived-at goals decided upon by pupils and teacher. The implicit pupil-responsibility for completing all of these activities with sustained intellectual vigor is apparent in the guide-sheet's organization.

[2] The writer is indebted to Roy O. Billett, teacher and colleague, for the structure here delineated.

— In a small filing case there are indexed cards, each one of which describes in detail a supplemental related activity for each goal on the guide sheets. The cards are dog-eared and bear the imprint of many fingers left when science-minded and science-able youngsters leave their marks on the cards as they left their marks on the teaching of science in this classroom. There is a pile of fresh cards, waiting for inventive young people to add their contributions for the future as they record designs of completed projects, their ideas for research, and as they catalogue collections or living things given to the school.

— There is plenty of space in this science room. There is space for displays of materials. There are bulletin boards. There is ample storage space so that the demonstration used but once a year can be ready on that day; there are terraria and acquaria. There are corners for private consultations of pupil with pupil, and pupil with teacher; and there is a table, near the room library, for quiet scholarly endeavor. There is a small shop, an electronics communication center, many filing cases with indexed current materials culled as by-products of individual or group research projects, and a weather station. Along one wall are twenty peripheral chemistry stations with gas, water, and fume-hoods. The room ought to be a sunlit barn. In it there is space to stretch one's mind.

— The science models, charts, microscopes, projection-equipment, cameras, telescopes, and precise instruments for measuring are the best that the community can afford.

Now, place every pupil, every year, in this room with a teacher who knows how to teach. The picture just painted is the picture of a philosophy of education, science section.

The superior science teacher: In the same kind of barn-sized room there is sometimes the superior science teacher. He is older, with six or more years of experience, probably in three schools. None of these schools had even an approximation of the ideal classroom when he came and when he left he took many of his own materials with him. His personal library, his educational and scientific periodicals, his own kodachrome slides of nearby and exotic environments, his guide sheets and files of related activities, and his classroom-proven *ideas* went with him to a new school.

Ideas are what distinguish the superior science teacher from all others. Every year this teacher learns more about his subject and about the potentialities of young people for interpretation of a world that is sensed as dynamic with change and promise; a world whose blueprint is even now in use to lay the foundations of science, human relationships, and world-plenty and peace. The unknown world of the future in which these science-minded young people will exert leadership depends as much on their human-relationship statesmanship as it does on their technical knowledge. There will not be a better world because there is more science, but there will be no world at all unless there is better and more responsible science. It is in this classroom for young adults that interpersonal relationships must be improved as science research goes on in heterogeneous groups. It is in this classroom that science, above all other academic disciplines, can teach young men and women what exactness means and what clarity of com-

munication is needed to transmit descriptions of processes so clearly that any listener may reproduce them. It is here that a gentle skepticism for every verbal substitute for the immediately-sensed or introspected entity arises and is nurtured. It is here, that first, second, or worse abstractions are recognized in advertising or in more subtle word-of-mouth propaganda. It is here that fears and unrational goals are brought out from the subconscious into an atmosphere of affection that is engendered as teachers, pupils, parents, and the members of the community are involved in the teaching of "science" — the only common denominator of the whole community. It is, as has been said above, the child's world which the teacher has dignified by bringing it into the classroom. More than that, science method is the only process of human thought which is easily recognized as being used by everyone, and so is not suspect. The child, from nursery school on into this golden-lighted barn, has exhibited to all his contacts his ability to see the form and structure of the real world — if science has been well taught. He himself defines, by extension, the superior science teacher, and, of course, the superior *teacher*. Such a teacher is known by his works, and his works will affect and effect the world of tomorrow.

Intellectual unrest: A product of good teaching is intellectual unrest, the "thorn in the side" in young people. The superior teacher will welcome disagreements and will make them the subject of group discussion and questions from pupils. Some such questions (each with science overtones) are these:

"Are other races less intelligent than *we* are?"

"Wouldn't it be better to gamble on more and better education for everyone?"

"What will we do in disaster if thousands of homeless people stream out of our cities and take our houses, our food, and our medicine away?"

"Why doesn't the government sponsor a group of young people, some of them scientists, who will think about problems of the government, and then tell the President what will happen if action *is taken*, and what will happen if it *is not?*"

"Why isn't it possible to take industrial arts if one is in the college course?"

"Why do teachers work in the television factory at night?"

"What would a utopian city and country be like?"

The transactions among parents, pupils, the school, and local and national leadership are furthered and enriched *during* the years in school, not after, as young adults work together under superior leadership in the good school. The climate of affection in our classroom is warm and all-encompassing. The thoughts of youth are long, long thoughts . . . , and they first and best can be translated into specificity and then into action *in* a good school, in the "sunlit barn."

Unique place of physics: For the young people who are committed, often as early as grade eight, to a science career the course which has for decades been called *physics* should be available. This course is essentially experimental and mathematical. The students who take this course can handle, with joy, all the mathematics which the high school offers. This means for many schools two years of algebra, some plane and solid geometry (but

not necessarily two courses in geometry); and analytical geometry and the beginnings of calculus. Hundreds of schools have been offering this program for many years. With this mathematics, and with precision equipment, there can be a good look at what science can be and what it can do in the laboratory and in the corners of the mind. The acceleration of gravity can be measured to close to theoretical values with Kater's pendulum. Solar cells can be calibrated with a potentiometer. Grating replicas show that the light from glowing tubes of helium is present in sunlight. Micrometers measure the inside diameters of glass tubes and so the constants associated with the surface tensions of modern detergents can be found.

Who should enter into this kind of intellectual adventure? Young men and women who delight in taking a twisted skein of problem-material and unravelling it — or who laugh at their own opacity when this seems impossible. Those who hope to be scientists and whose mathematics grades and science achievement tests do not predict success, can find out, without equivocation (given a good teacher), whether they cannot only "pass" *college* physics, but can go from there to more and more abstract science and mathematics; they should take the course to fail it or to mature into it. And finally, those young people whose parents hope for careers in science for them, careers which they themselves are not sure they want; they should take the course and with honesty do their best. If they fail, this will be notice to their parents that science is not for them.

Physics is taught in the same sunlit barn. The members of the physics class may have taken many or all of the courses which have been offered there. But this most demanding and most rewarding of all intellectual tasks, the classical physics adjusted for their current environment, is for the science-minded; indeed, it is for the science-able only.

Evaluation in the secondary school: The National Science Teachers Association has at work a Committee on Evaluation whose chairman is Dr. Paul L. Dressel of Michigan State University, and of which committee the writer is a member. Their first project has been completed by Dr. Clarence Nelson,[3] also of the Michigan State University. His *Let's Build Quality into Our Science Tests* contains rubrics for teacher-made tests. There is a brief methodology of test preparation. Then there are given many sample items of almost every new type that is being tried by university and commercial testing teams. Some of these involve scientific attitudes, problem-solving in two and three stages (where a first decision must be justified by the testee), or the ability to resist attractive easy but incorrect solutions of environmental problems.

Nearing completion and scheduled for publication in mid-1959 is a complete survey of all science tests for the secondary school which are available to teachers nation-wide. Data on costs, range, subject-matter, reliability and validity are given. When available, the population of the try-out sample is given so that teachers may decide whether the test is valuable for their own classes.

Unsolved problem in testing: Test-makers would like to anticipate the schools' needs by including items which measure those achievements of able young people which are accepted as being desirable by writers of yearbooks and by national committees. The schools move slowly, however, and

[3] Clarence H. Nelson, *Let's Build Quality into Our Science Tests*, National Science Teachers Association, Washington 6, D. C., 1958, 24 pp.

it is no news that from ten to fifteen years ordinarily pass before well-accepted new practices are found in a majority of the schools. If a test, then, has a substantial number of items the answers to which are not forthcoming from the memories of the testees, because they have never been taught about the items in science classes, the test will be difficult — too difficult to be accepted by enough teachers to make it financially successful. Many test publishers have, out of their real desire to help in changing science education, been willing to forego immediate profits and have waited for the schools to catch up. The test makers have been agreeably surprised to find that this procedure has measurably hastened change in science teaching. (The same situation holds for texts. Many good texts have influenced, for the better, classroom practices and educational philosophies.)

Some programs now under way bid fair to change practices rapidly. The American Chemical Society has been preparing tests through one of its committees for five years. They have experimented each year with a few items on scientific method and on scientific attitudes. The College Entrance Examinations, it is reported, have tried many types of questions across the country, and are presently (1959) evaluating the items with a view to incorporating some of them in the body of forthcoming tests as scorable items. The Physical Science Studies Committee, mentioned previously has worked with the Educational Testing Service of Princeton, New Jersey, on the production of a physics test which will measure achievement of pupils who have been working in the new high school physics course created by the P.S.S.C.

The National Science Teachers Association would welcome any suggestions for experimental forms of testing or for new types of items. There is evidence that there are unusual and valuable test materials which have been invented by teachers who have so far failed to publish their work and their educational findings. Of all teacher-made materials, tests are likely to have the widest applications and to be potentially the means for improving science education at the secondary level.

Chapter V

WHAT RESEARCH SAYS ABOUT CURRENT STATUS AND TRENDS IN SCIENCE EDUCATION

Indications of Changes: In Chapter 3 there have been reported changes and the current status in the elementary school science program of today. To summarize briefly then, there are, at the present time, nine definite current trends in elementary science:

1. There is an increased emphasis on elementary science, either as a separate subject or as a part of the social studies. The present authors believe that science lends itself well to the social studies program, but that there is no need for science to be "integrated" under the name of social studies at all times.

2. School systems all over the nation are constructing more definite courses of study or curriculum guides, which points up the fact that there is now in progress much less incidental or accidental science being taught at the elementary school level.

3. More emphasis is being placed on seeing relationships in science and in problem-solving, rather than on unrelated facts. Although there is still much lip-service being offered in regard to problem-solving, most teachers and administrators are accepting the fact that science textbooks are *not* reading books, but are reference books and stimulators. It should constantly be kept in mind that science, however, is unique in its construction in that there exist certain definite facts to be learned *before* problem-solving may be used to its fullest capacity. The child learns certain relationships and understandings before problem-solving is presented and learns further facts and principles by involving himself in the *solving* of problems.

4. There is more *doing* and less hearing and *reading about* science at the elementary school level. In this respect, then, there is evidence of more *experimenting* and *experiencing.*

5. There is more effort being expended in adapting elementary science to the needs, interests, and abilities of the child. This is a good sign, and should prevent some dangerous thinking that elementary science is just "watered down" secondary science.

6. Community resources are being used to greater advantage. School teachers and administrators, working together, are compiling lists of local places to visit, and local peoples, friends, relatives, and neighbors to be called upon for help in enriching the science program.

7. There are more workshops in science education than ever before, as well as many types of in-service programs in science enrichment. This is encouragement anew that teachers and administrators are working shoulder to shoulder to broaden the science curriculum for today's children.

8. More time is being spent on research to discover how children learn science and how science fits into the total learning situation. The present writers believe that we do not expect enough of our children

today. Research indicates that young children can do more in science than was formerly thought. Studies show that the sources of science information are many.[1]

9. There is finally a recognition of pupils with special talents and abilities in science at the elementary level. Blackwood[2] says:

> "Expect and require bright children to know more than other children. Though there are usually certain understandings that most children in a class should know about topics being studied, there is no reason for limiting the knowledge of all children to an agreed upon minimum. If given the opportunity, the encouragement, and the time, bright children will acquire more knowledge. But they need help, too, in knowing where to get information and what is expected of them. Bright children ought not to be limited either to what the teacher knows about a particular subject. A mark of a good teacher is to find that her pupils are outstripping her. They should be congratulated for it."

Research in elementary science: Research in elementary school science is even now passing through the stages which general educational research has experienced. There are many opinions reported, and there are several schools of thought as what the major aims of elementary science should be.

Some of the questions listed below have stimulated investigators to attempt to sample the status of elementary science in the whole country. Other studies have reached out for opinions from practically every person who has had wide experience in teaching, writing, or supervising elementary science.

1. Why do we teach science to elementary school children?
2. Is there a pattern by which problems can be solved by the child? Can the methods of problem-solving be taught to pupils by willing teachers who are untrained in science?
3. Should a course of study or guide of some type be planned and used?
4. What evidence from research is there that particular *topics* or areas should be taught at certain grade levels?
5. Can *principles of science* be used as structures for science learning?
6. Should the child's interests be used as a major basis for setting up courses?
7. To what extent should science be used as a vehicle to teach basic skills?
8. Can the results of scientific methods and procedures used and taught in elementary-school science be expected to produce better attitudes toward the solution of current controversial problems?
9. What are some of the science misconceptions that cripple the full growth of children?

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[1] Pearl Astrid Nelson, "The Acquisition of Concepts of Light and Sound in the Intermediate Grades," Unpublished Doctoral Dissertation, Boston University School of Education, 1957, p. 177.

[2] Paul E. Blackwood, "Teaching Elementary Science to Gifted Children," *The Science Teacher* (September 1958) XXV p. 262.

It is indeed encouraging to know that today there is much less of the incidental and accidental teaching of science at the elementary level. In this respect Ballou[3] says:

> "An adequate science program cannot be totally incidental. A planned program in science is necessary for making sure no area of science is neglected. For example, the children in the classroom to which a cocoon is never brought have a right to know about the metamorphosis of an insect, just as do the children in the classroom to which a cocoon is brought. The planned science program should provide for the development of major understandings in each of these areas: animals, plants, rocks and soil, weather, simple machines, sun, moon, and stars, and foods and health. How much children learn about each area will depend upon their interests and abilities. The program must be flexible. A rigid curriculum which designates the study of weather, for example, as strictly a second grade subject which the first grade dare not mention is not advisable. As pupils mature through the grades, additional learnings on each subject should be possible. All there is to know about weather cannot be learned in a single year! Perhaps that is the reason why most writers of modern science texts include something in each of the areas mentioned for each grade level."

Providing for the bright and gifted: There is currently a growing trend to identify ability in science at the earliest possible moment, and there is a concerted effort to develop test-instruments which may help in identifying special aptitude in science. In regard to this, Navarra[4] states:

> "This concern, as we all know, has been instigated by a developing shortage of research, engineering and teaching personnel at all levels. Further impetus has been given to this work by recent publicized advances of Russia and other countries in the area of science. Of much significance is the new awareness aroused in the public. Industry and industrial leaders in various sections of the country have had a tremendous influence in the mounting drive to press for more adequate development of the science aptitude latent in the young. If one listens carefully, it becomes crystal clear, we are far from the peak of the pressure which will be directed toward the elementary school. Now, this is not without its compensations. The early discovery and development of science aptitude could prove to be a very valuable, significant trend. However, it would seem to be quite pertinent to raise the question as to *how* the aptitude would be developed. In what way, if any, would the intensive development of latent ability in science differ from our current, better programs of Elementary Science?"

[3] Mildred Ballou, "Science For Six Year Olds," *Science Education* (October 1958), Vol. 42: p. 302.

[4] John Gabriel Navarra, "Elementary Science For A Changing World," *Science Education* (October 1958), 42: p. 314.

By *giftedness*, the writers refer to a general intellectual ability, but, of course, the term is also used to cover certain specialized abilities, which are widely regarded as varieties of giftedness. Musical, artistic, and mechanical varieties are most easily identified by psychologists, and each of these three types of abilities has been found to vary from individual to individual. Each appears to be similar to general intelligence in apparent origin, constancy and function, and yet not one of these is apparently related too closely to intelligence. There are other abilities which are popularly thought to be manifestations of special gifts, but psychologists usually regard them as part of general intelligence channeled into special areas of interest and training.

Since January, 1958, when our earth satellite, *Explorer*, was launched there has been a definite change in attitude towards the academically talented pupil, and especially towards the boy and girl who is talented in science. Some educators are acknowledging "science-giftedness," and are exchanging ideas about characteristics and potentialities of these students. In regard to the academically talented, Stalnaker[5] says:

> "Although the concern for the education of an increased number of our talented students is not new, the obvious accomplishments of the Russians have given a tremendous impetus to the efforts to capitalize on our human resources. It is from the academically talented pupil of today that most of our trained minds of tomorrow will come, and, if there was ever an age when such minds where in high demand, this is the age. We can identify the able student, even though it be a complex job. We can pay these students to go to college, and, if the price is set high enough, we can capture virtually every one of them. But before we go hog wild, should we not recognize that money alone is not enough? We must change the attitudes and values of the American public — and this is no easy task — before we can attract a larger proportion of students into the scholarly and scientific fields. . . . As we begin this conference to exchange ideas about the academically talented pupil, we may profitably pause to survey very quickly the general picture of education and the part it plays in our national life and how we as a nation regard scholarship, learning and the disciplined mind. In this way we may be able to understand better what our problems of identification are. The selection process is improved to the extent that it takes into full consideration the past experience and opportunities of the individual, and interprets his present performance in the light of both his background and the possibilities for his future. Our problem, briefly, is to predict not only those who should succeed and will, and those who are not expected to, but do succeed. Of course we want to do even more. We want to identify, in the long run, those who will succeed and will not thereby be made into such conformists that they will never themselves create or contribute to the improvement of the system in which they succeeded."

[5] John M. Stalnaker, "Methods of Identification–the Complexity of the Problem," *The Identification and Education of the Academically Talented Student in The American Secondary School*, National Education Association Conference Report, Washington, D. C. (February 1958) pp. 19–20.

The portrait of the science-minded child is a very interesting one. He is above average in intelligence and is able to do many things well. He possesses many original ideas which are a great asset to him as well as to his classmates. He is eager to discuss his findings and to share them with his friends. He is able to often astonish his elders with knowledge and understanding on topics that interest him. Children who have special abilities in science have alert minds which can grasp fundamental principles so well that they are able to think about matters at a mature level far beyond their years.

Behavior of science-prone students: What are some of the behavior-patterns of science-prone students? From a recent study, Brandwein[6] reports the following characteristics:

1. Outside of school the majority tended to individual sports: tennis, cycling, fencing, walking. Very few in team sports: basketball, baseball, football.
2. Major part of the time spent in reading and other intellectual activities, homework, listening to music, school club activities. Minor, although significant, amount of time in social activities such as dancing.
3. Major part of time in self-initiated, individual projects: astronomy, "ham radio," stamp collecting, classical music, learning foreign languages or musical instrument.
4. Tendency to classical music, bridge, and serious reading of classics (Dickens, etc.); do crossword puzzles and acrostics.
5. Tendency to read "serious" magazines, e.g., *Harper's, Time, Scientific American, Saturday Review.*
6. Tendency to go to the movies less than once a week. Tendency to go to theater.
7. Activities joined in school more of discussion type: Language Society, Problems of Civilization, Science, Chemistry Club, school paper, school magazine.
8. Approximately equal tendency to earn extra money in after-school work, but mainly in baby sitting (girls).
9. Strong tendency to do social-service work, e.g., read to blind, collect for Red Cross, church activity, messengers, civil defense.
10. Tend to be conservative in clothing, although within norm, e.g., most boys wear ties, rarely take on "fads."
11. Vast majority buy books for personal library.
12. Tend not to smoke till senior year, or not at all.

[6] Paul F. Brandwein, "Stimulating the Eureka," *Metropolitan Detroit Science Review* (December 1958), pp. 15–16.

13. All plan to go to college.

14. Almost never get into difficulty with teachers or disciplinary problems in school over school work. May disagree with teachers over interpretation of subject matter.

15. Almost all the parents had a post-high school education. More than half were graduates of colleges; a high number of graduate schools (Ph.D., M.D., Law, Engineering, Accounting). A high minority in professions.

16. A tendency for parents to own a substantial library (500 books or more). A vast majority with 200 books or more.

17. Vast majority of parents with ambitions for professional life for their children.

18. Average of children per family, 1.2.

19. Twenty-four of the 30 were the first child, 16 were the only child.

An eight year old child can become an expert on dinosaurs as a result of his intense interest in the subject. He may spend his free time in museums, reading numerous books and making large drawings of the monsters. He may lecture to his schoolmates on the subject. This child may be said to have an advanced *intellectual curiosity*, which leads him to search out facts for himself, as well as to apply these facts to new situations. These children, then, are capable of thinking logically, and approach the adult level. Science-minded children often develop their own interests and set themselves intellectual goals. They may give themselves tasks such as taking apart a clock and putting it together again, or investigating the water-cycle. We have had these science-minded pupils in the world always. John Ericsson, inventor of the screw-propeller, did the basic thinking and experimenting which led to his invention while working on toy boats at the age of nine.

It is true that many science-minded children make only slight contributions to science in their later years, because their gifts were not developed or their abilities well trained. These gifted children, in any particular area, and not science alone, deserve a special kind of schooling that is worthy of their gifts. Their training must offer incentives, exercise their creative energies and be conducive to true learning and experimentation. They need encouragement in their explorations, sometimes special tutoring or training under a well-trained, able, teacher. Although these science-minded children may devote large amounts of their leisure time to scientific activities, the wise teacher will be prepared to offer them encouragement and guidance in other fields of endeavor also.

It is true that children who are mentally superior may not tolerate the ordinary class routines and often tend to regard them with indifference. To motivate these gifted children, the teacher must be prepared to offer extra resources. Insisting that superior students perform a task again merely because the other children have not completed their work certainly is not

stimulating; nor will tasks such as running errands or cleaning the chalkboards satisfy. The problem of fitting the school to the child is puzzling educators as never before.

To provide acceleration in learning for science-minded children, two methods are being tested. The first provision deals with the introduction of individual enrichment activities into the regular classroom. This curriculum offers the mentally superior pupil an opportunity to exercise initiative and originality. Enrichment units in a science course may include the "question-box method." A question box dealing with science is opened once a week and the children's questions found in it are discussed by a special teacher. Another form of enrichment for the science curriculum is the science club. Field trips, contests, and community projects relating to the science program are often handled in this manner. Science fairs or exhibits have also proven to be of special interest to many talented children in elementary and secondary schools alike. Hobby periods may be employed to enable pupils to work on special projects and reports. Another method which is being experimented with is that of grouping according to ability, so that science-minded pupils are placed in special classes for portions of the day or week.

Instead of abstract science, science-able children of elementary school age benefit most from living science which involves real experimentation with the phenomena of the immediate environment. Experiments and projects in which they have shown interest are assigned to them. Discussion periods are provided and the children are encouraged to read and to do experiments dealing with their chosen topic. Special book lists are prepared for these children and programs based on their reading are presented to the class. Exhibits, demonstrations, films, and trips are available so that information may be gathered and used.

The teacher of the science-minded: The teacher of the pupil who is talented in science should have a decided reduction in workload, with the additional time used for necessary planning for enrichment of the curriculum. The special facilities offered for use in the education of the science-prone pupils will be wasted if planning-time is not provided to ensure maximum use of the project rooms, tools, visual aids, and library aids. The talented pupil has needs similar to those of the research scientist, and wastage of manpower and equipment must be avoided.

Changes made without research in Secondary Science: Some changes have been made without the benefit of research, nor have they received the prior approval of the ultimate consumers — teachers and pupils. Some programs are here listed:

1. Since about 1930, biology has been a fused course, made from fragments of college-type offerings in high-school botany, zoology, physiology, and hygiene. The fusion process had started a decade before, but the framework of the elements is still evident in 1959.

2. Advanced biology, often designed for prospective nurses or medical technicians, is increasingly offered.

3. Since 1950, biology has been available in grade nine, leaving room for three more years of science.

4. The course called physical science, largely physics with some chemistry and generous chapters on astronomy and geology, is generally accepted as satisfying all or part of a science requirement for college entrance.

5. The American Chemical Society's testing program, now about five years old, is refining and enlarging its instruments.

6. The Physical Science Studies Committee,[7] stemming from the ideas of a group of famous scientists who were convened by Professor Jerrold Zacharias of the Massachusetts Institute of Technology in 1956, has strongly influenced physics-education overnight. The Committee felt that a new high school physics course, together with a new philosophy which could be transmitted to young people, could be implemented quickly if money and help could be found. Both were found — the one from foundations, private and public, and the other from the ranks of college professors, high school teachers, and from the years of invention and tryout of good classroom demonstrations. Essential to the program's success is the slowly expanding training program, in which excellence is demonstrated. As the teaching increases exponentially, five more years will see, in every corner of the country, a center for learning about the physical world, where new methods of teaching are joyful intellectual enterprises. It is planned to investigate teaching procedures in other sciences (and in mathematics) to see if a similar process can speed the day when good science or mathematics demonstrations, presented with a vigorous method, will be tried in every school in America.

7. Earth science, which has survived from its physiography and physical geography days, is resurgent. It is, of all the sciences, perhaps best suited to the adventurous student who is not necessarily college-bound, for it includes meteorology, geology, and navigation. It suggests exploration into caves, over mountains, under the sea and into space.

Changes in spite of research: Challenging some research, which has been often reasonably conclusive, the schools have continued to allow many changes to take place which cannot but weaken the education of the science-able and the science-citizen. Laboratory periods have been shortened or dropped in biology, sometimes in chemistry. The cook-book chemistry laboratory persists, when it has been shown that it contributes little either to achievement or interest. As in other subjects, the memorization of facts for the sake of facts can be shown to have poor efficiency.

Science Principles: The studies by Francis D. Curtis[8] and his pupils at the University of Michigan on science principles as bases for the organization of the understandings which can be obtained from the science

[7] 164 Main Street, Watertown, Massachusetts.

[8] Curtis, Francis D., *A Digest of Investigations in the Teaching of Science in the Elementary and Secondary Schools*. Blakiston, 1926.
———, *A Second Digest of Investigations in the Teaching of Science*, Blakiston, 1931.
———, *A Third Digest of Investigations in the Teaching of Science*, Blakiston, 1939.

environment, are challenging. *Principles* are not topics or areas. They are not definitions or labels. They express, in declarative sentences, relationships between things and processes of the real world. A few samples will be informative.

> "Protective adaptations aid in survival."
>
> "Matter and energy may be transformed but they cannot be created or destroyed."
>
> "Two groups of forces are constantly acting on the earth's surface, one building it up, the other tearing it down."
>
> "All substances are made up of small particles called molecules. These are alike in all samples of the same substance but are different in different substances."
>
> "Like electrical charges repel and unlike electrical charges attract."

There are several science textbooks based on these principles insofar as the framework for learning science is concerned, also; in Quincy, Massachusetts and in Denver, Colorado, the use of principles has been advocated to clarify some of the aims of the elementary school science course; they have been used for two years in Springfield, Massachusetts, in a secondary school as a trial basis for the total classroom teaching of science.

Principles research at Boston University: From 1951 to 1956 more than 20 masters theses and one doctorate thesis[9] were completed following a pattern whose rationale is as follows:

1. The basic generalizations, concepts, or principles of science are useful for organizing the variety of experiences found in the real world.
2. These principles are finite in number, and they have been scientifically and educationally stated in declarative sentences.
3. There are too many principles which are assigned to the twelve to fourteen years of the school program for their learning to be undertaken in one or two courses at the secondary school level; further, to leave them to this level would negate younger pupils' high interest in science and to delay pupils' need for explanation of the environment.
4. They should be taught and learned; i.e., their final acquisition should not be left to chance.
5. It is certain that many principles require for their understanding the sophisticated maturity which comes from multiple exposures to applications of the principles. They require also immersion in a socioeconomic milieu which uses the principles.
6. It is likely that starting about the second or third year of school there will be certain of these principles which will be needed by a child of *whatever maturity and socioeconomic background* (within reasonable bounds of normalcy of intelligence, but including even deep-rural cultures) for accurate interpretation and classification of the events in his environment.

[9] Herbert G. Oxendine, "The Grade Placement of the Physical Science Principle 'Sound is Produced by Vibrating Material'." Unpublished doctorate dissertation, Boston University School of Education, 1953.

7. It is a fact that teachers, textbook writers, and children's encyclopedia editors have to make decisions as to the grade-placement of groups of experiences which they hope will finally be seen to be similar and which can be subsumed under a generalization, concept, or principle.
8. It may be that some relatively simple classroom research will show educators at about what grade levels a principle may be understood.
9. It is assumed that even with the problem of the varied experience-background of children, if many of the children in a particular grade have been able to profit by experiences which they have had so that they have made progress in understanding a principle, then others in the group can relatively easily (through demonstrations, simple research, group study, audio-visual materials, and teacher direction) also come to a real operational use of the principle. Briefly, it should be easy to supply enough common experiences to children who lack them to bring them "up even" with the children in the grade, and so be able to test-and-teach and teach-and-test to the point *where no common experiences* of these children in this culture *will go unrecognized — from then on.*
10. Research seeking to discover the applicability of the nine rubrics above is initially forced to a more precise stage than is desirable. Control groups must be set up. Every experimental group must have identical conditions. The experiment should be replicated in many towns and over a bracket of at least two grades.

Successes and questions: After many pilot studies, a technique was worked out which is best described by Oxendine[10] in his dissertation:

> *Purpose of the Study.* — The grade placement of scientific principles is an important aspect of teaching science at the elementary level. Heretofore, there has been very little experimental research done in this area. The investigator using a classroom demonstration technique took the principle, "sound is produced by vibrating material," and endeavored to discover at which grade level in relation to mental age the teacher may expect to get maximum learning, if the technique as is described in the following chapters of this study is used.
>
> *Scope.* — This study included fifteen elementary schools in New England. Five schools were selected in each of three areas, urban, urban fringe, and rural. This constituted a stratified sample based on the environment of the New England area. Seven hundred pupils from grades four and six were used in this study.
>
> *Procedure.* — Pupils were pre-tested to establish their initial knowledge of the principle, "sound is produced by vibrating material." The pupils were then randomly separated into two groups, experimental and control. The experimental group was given a lecture-demonstration on the principle, "sound is produced by vibrating material." The control group in another room was given a silent reading

[10] Herbert G. Oxendine, *ibid.*

> period. Both groups were given the same post-test. The post-test was the same as the pre-test, except that the responses to the items were arranged differently (scrambled) in the two tests. . . .

Using valid and reliable tests, it was found that at the fourth grade 37 percent of the pupils in the study could score perfectly[11] on the test, and at the sixth-grade level 57 percent reached the criterion score. (In the study, sixth grades had median mental ages of 11–12.)

There were more than 20 such studies conducted, many of them supervised by Oxendine who went into the field with the test teams. Replication of selected principles-and-grade combinations has established a reasonable stability of placement of a few principles. The method would seem to be particularly suited for action-research by teachers in their own schools, districts, or counties.

One question which arises is pertinent. How can it be said that the artificial experimental situation is measuring anything about science learnings? Children are not allowed to participate in the lesson; a strange person comes in and does strange experiments. They must take a test the form of which may be unfamiliar; they have never had any formal science taught to them. All these are barriers to learning and are negative indications for success. If, then, children in grades 4–9 can do so well with the recognition of the binding-power of a new concept, in such poor educational situations, how much better would they do in the free and challenging atmosphere of a good classroom? How much better can children do *intellectually*, with the firm and precise organization of science as delineated by the principles of science, than we have expected?

Whitehead answers with:[12]

> " . . . different subjects and modes of study should be undertaken at fitting times when they (pupils) have reached the proper stage of mental development. . . . It is not true that the easier subjects should precede the harder. On the contrary, some of the hardest must come first because nature so dictates, and because they are essential to life."

Or to paraphrase a current saying, "Never underestimate the power of a child to generalize!"

Other research at Boston University: Some other science education areas which have been investigated on a national scale so that their findings may carry some suggestions for changes in teaching are listed below.

1. What misconceptions about science do ninth grade pupils have? They are many, and the implication of one study is that science teachers could well spend some time in showing (for telling is not changing) pupils that many of their common beliefs are thought by scientists to be untrue.[13]

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[11] All items (of about 20) correct; *less* a number (1–2) determined by a standard error technique.

[12] Alfred North Whitehead, *The Aims of Education*, The Macmillan Co., New York, 1929, p. 25.

[13] William Rogers, "A Determination of the Prevalence of Certain Important General Science Misconceptions," Unpublished doctorate dissertation, Boston University School of Education, 1956.

2. What are the scientifically, socially, and economically defensible concepts about the use of beverage alcohol? World figures in the field of alcohol-use gave their opinions as to exact statements about alcohol-use. These proved to be few, but they are now a reasonable base for further investigations as to how best to teach the concepts (as required by law in 48 states) to children.[14]

3. Can a program of inductive laboratory teaching in chemistry produce significantly superior learnings than does the usual "laboratory manual" procedure? The answer is yes.[15]

4. What topics do biology teachers consider most important and how well do their pupils do on tests concerned with these topics? This nation-wide study conducted with the help of the National Association of Biology Teachers found that conservation and human physiology were at the top of a list of important topics; and that pupils who took a test, which was conceded by all the teachers involved to be fair and understandable, could obtain scores close only to the 50 percent level on the test.[16]

5. What are the backgrounds of some of the superior science students who were winners or had honorable mention in the Westinghouse Science Talent Search? This well-known study has given us a better picture than had been available of the backgrounds and the ways of this group which is augmented each year. They are different from those able young adults who have high interests in other than science fields.[17]

6. How do able science-minded young people differ from other able young adults in their scores on a non-verbal test seeking to discover whether a group of occurrences (represented by pictures) has a single unifying science principle? There have been several of these studies,[18] which are completely non-verbal, employing pictures of the common cultural environment of pupils who take the tests. The tests seem to have a reasonably statistical cutting edge for the separation of able science-minded pupils from other pupils of the same intellectual abilities.

General considerations for research: If there is any aspect of science education research which needs thoughtful consideration, it is in the non-parametric measurement of human traits. The techniques of research in

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[14] Arthur Giovanngeli, "The Selection, Development, and Objective Evaluation of Concepts in Alcohol Education . . . ," Unpublished doctorate dissertation, Boston University School of Education, 1954.

[15] Sr. Ernestine Marie O'Connell, "The Comparison of Inductive and Deductive Methods of Teaching High School Chemistry," Unpublished doctorate dissertation, Boston University School of Education, 1958.

[16] John Tyrrell, "A National Survey of the Opinions of Biology Teachers As to the Most Important Areas in High School Biology . . . ," Unpublished doctorate dissertation, Boston University School of Education, 1958.

[17] Robert D. MacCurdy, "Characteristics of Superior Science Students and Some Factors That Were Found in Their Background . . . ," Unpublished doctorate dissertation, Boston University School of Education, 1954.

[18] John G. Read, "A Non-verbal Test of the Ability to Use the Scientific Methods as a Pattern for Thinking," *Science Education*, 33:361–6, December 1949.

social and human relations are often more applicable to educational research than are the fine-grain statistical studies of agricultural and industrial sampling. Nevertheless, if statistical techniques are needed, they should make use of nation-wide and socio-economic-fair testing techniques. Large scale studies are expensive and require the use of electronic computers to handle the multi-variate attack on problems with many factors to be controlled or equated. This would seem sharply to define the kinds of research possible to a staff in science education.

Respect for educational research will grow only as fast as rubrics for national or world action can be written by mature research. The present stage of the art is largely descriptive. First causes are perhaps impossible to know; but the search for the "why" instead of the "how" should be undertaken more often. For what reasons do children fear arithmetic, later avoid chemistry and physics? What factors make expositional science material difficult to read, and so delay success in coming to grips with science problems which are usually posed vicariously in verbal form?

Long periods of time working with a few children or young people are needed. It is necessary to get their confidence so that their own introspection can contribute to finding reasons for their success or failure in science. Enough of these intimate person-to-person studies will eventually disclose some if not most patterns of damage or superiority common to young people.

Perhaps national teams, working on facets of an agreed-upon problem, might resolve the dilemma stated above. The several times that such proposals have been made, they have failed of striking fire largely because of lack of money and communication. If any foundation is seeking a new dimension to explore, this kind of cooperation is worth an investment. The National Science Teachers Association can and does speak for the science teachers of America. It has in its membership inventive men and women who would be glad to invest thought and time in such a project. The National Association for Research in Science Education should be the guiding advisor. It is time to test the combined powers of research in science education which have been growing unnoticed for three decades.

In addition to a national research center (which should be in the offices of the National Science Teachers Association in Washington) there are available all the regional, state, and district organizations of NSTA. It would be indefensibly inefficient to attempt to set up a competing network seeking to enlist science teachers' time and interest.

There surely are not more than a few hundred dissertations and studies, of stature, which would need to be classified and placed in a hierarchy of growth in knowledge of the teaching process as it applies to science education. Inherent in this proposal is the belief that science teaching is sufficiently different from other kinds of teaching to warrant a special study of the content and method of the discipline.

Chapter VI

TEACHING SCIENCE IN AN ATOMIC CLIMATE

Orbiting — general trends: An important problem is whether or not to use textbooks in our science teaching, and if not, how then to use them effectively. Supervising personnel often tell their teachers in elementary school that science texts are not readers, and should not be used as such. Often the directive is left at this point — and so are the many splendid science books. Some educators boast that they do not use texts at all in elementary science, and usually this means that neither are trade books nor any types of written materials utilized in the science work in the grades. The general trend, however, is to use the science textbook as would be used any type of tool for learning, as a history text or an atlas is used. Pupils do their science reading to answer questions — about why an electric current flows, to find the difference between a star and a planet, or to discover the habits of other carnivorous plants besides those of the Venus Fly Trap. They learn to glean the information they want, and to gain power in critical thinking and problem-solving.

Science teaching must, along with imparting facts, develop critical thinking in relation to problem-solving. If teaching science neglects this part of the teaching process, then only part of the task is being done. David Russell[1] says in regard to critical thinking:

> "Critical thinking, as usually used, is an omnibus term including such varied activities as problem-solving, syllogistic reasoning, and propaganda analysis. — The young child, appraising his bridge made of blocks or questioning his mother's statement that Santa Claus comes down the chimney may be thinking critically. — Critical thinking is probably not a unitary ability so much as a collection of related abilities. One child may be good at locating related objective evidence but not at determining its relevancy or irrelevancy. Another child may be good at comparing two conflicting statements but not at arriving at some conclusion about the opposing points of view. Children may differ in the ease with which they make theoretical analyses and in their ability to carry them over into practice."

There are many school systems and teachers now making wide use of science experiences built around the solving of problems that are significant to the pupils. There is also effort being made to use actual experiences whenever possible to make science more meaningful. Blough[2] says in regard to trends in elementary school science:

> "Administrators, teachers, and pupils are working together to an increasing extent to plan and carry out an effective program. These efforts have resulted in much local in-service activity designed to meet the specific needs of teachers and others. Increasing effort is being made to determine how science can make its unique contribution to the development of children and also fit into the total learning situation."

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[1] David H. Russell, *Children's Thinking*, Ginn and Co., 1956, pp. 301–2.

[2] Glenn O. Blough, Albert Huggett, and Julius Schwartz, *Elementary School Science and How to Teach It*, Dryden Press, Revised Edition, 1958, p. 8.

Research indicates that there is definitely an increased emphasis on science as an integral part of the program in the elementary school, either as a separate subject or as a part of some other subject. The present writers feel that although mathematics and science are integrated normally at the secondary school level, the melding of arithmetic and science at the elementary level is usually forced and artificial.

Glenn Blough speaks of the sense of security which a teacher must have to do to be able to answer the questions posed by the average child in the elementary classroom. He feels that the teacher has every right to expect some type of help from administrators to achieve this security. They should understand the situation thoroughly and realize that telling teachers "to learn with the pupils" is, today, scarcely an adequate solution. What does the elementary school science teacher need? Blough[3] says:

> "She needs some background in order to direct a satisfactory learning experience in science just as she does in any other area. Telling her that science is a study of the world around her, that every-day happenings and the on-going program in her room are full of possibilities, hardly helps her at all, since she's not likely to know how to identify these happenings and possibilities."

There still exist some schools which have no science course of study or curriculum guide. However, since the old accidental science approach is definitely waning, these schools are now scrambling furiously to obtain consultants in the field of science, or are at least establishing science conferences among staff members to decide what to do about organizing a definite science program.

Blough[4] agrees that every teacher needs some type of a guide — an outline which will give her a feeling of security and structure as she plans her science offerings. In this respect he says:

> "The first thing she should have is an outline, a course of study or some sort of content guide that she can lean on until she gets some satisfying science-teaching experience. After that, she can begin to branch out and use some originality. The course of study needs to be definite but not too rigid. It must be detailed enough to be helpful. It can come from the same sources as any other helpful outline — from an in-service project, from material borrowed and adapted from some other school system, or from the contents of one or more good series of science books. A successful guide cannot be made by pooling the inexperience of the staff. Somebody in the school system must become informed about trends in content, organization and methods. This may be the principal, a teacher with special aptitudes and interest in science, or a consultant or supervisor who is willing to become informed — or all three."

Subsurface probing — specific events and programs: — At this time (1958), there is unprecedented public concern about education in the *high school*, and well-established programs are being scrutinized and new programs are

[3] Glenn O. Blough, "Miss Evans Needs Help," *NEA Journal*, November 1958, p. 542.
[4] *Op. cit.*, p. 543.

being planned. However, interest is now increasing in elementary school curricula and methods of instruction. There is a growing realization among educators that, if there are any changes to be made in the secondary program, certainly the elementary program will be affected. A stepped-up science program in junior high and senior high must have its beginnings in the elementary school. The lay pressure for investigation into secondary education is now being deflected to the elementary school. This is especially true in the science program. Much of the talk on re-vitalized education in the elementary program comes from people other than educators. In this respect, Frazier[5] writes:

> "And we are properly uneasy in the elementary schools, for much of the talk about departmentalization, ability grouping, new bases for promotion, and the like comes from people who lack our understanding of the values and the vision embodied in a modern program for children. If new expectations are to make sense, they must be formulated with us — not for us. Of course, even if we do nothing, eventually we will be consulted. But waiting is not enough. Waiting may mean spending the next decade in struggling through a second growth of discarded solutions."

Teachers, elementary or secondary, need a place at the planning table of *any program change*, and especially so during changes in any science program. Our values must constantly be re-sharpened, so that new ideas and new visions will become clearer with study.

What are some of the better programs in science education in our nation's schools, and why are they considered better? In Arlington, Virginia,[6] a planned program exists where suggestions are given regarding suggested activities in social studies and science.

1. Organize in vertical files according to social studies and science topics materials from such sources as children's current events magazines, newspapers, news magazines, *National Geographics*, discarded textbooks, and pamphlets.
2. Make annotated bibliographies for use in unit study.
3. Preview films and film strips for class presentation.
4. Prepare material on easy reading level for use of small groups.
5. Make samples of different types of maps, charts, exhibits, experiments, and art projects which have been developed in unit work.
6. Do the research necessary to prepare special day programs for presentation to other groups.
7. Evaluate own achievement and understand where concentrated effort is needed. Plan for intensive practice in areas of weakness and evaluate growth.
8. Do research necessary for the classification of collections, such as rocks, shells, minerals, leaves.

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[5] Alexander Frazier, "New Expectations in the Elementary School," *NEA Journal*, November 1958, p. 547.

[6] *Suggestions for Working With The Gifted*, Arlington County Public Schools, Arlington, Virginia, 1956.

9. Reproduce experiments seen on such television programs as "Watch Mr. Wizard."

10. View television programs related to science and social studies, such as "Ask It Basket," "Zoo Parade," "Omnibus," "Wide, Wide World." Evaluate programs and compare with authoritative writing in the field.

11. Do research necessary for setting up an aquarium, a terrarium, or a class museum.

12. Help evaluate textbooks being considered for County adoption.

13. Help select library materials for social studies and science.

14. Observe and record findings on such things as change in colors of fabrics in the sun, growth of seeds, effect of soil and light on growth, changes in temperature and humidity, the movement of the sun, the apparent position of stars at different seasons, formation of clouds, and length of days.

15. Devise experiments to demonstrate science learnings.

16. Read widely in areas of special interest in social studies or science.

17. Demonstrate science understandings through the construction of models, such as pulleys and levers, telegraph, telephone, wheels, motors.

18. Do research necessary for the construction of maps or globes showing such geographical information as products, population distribution, rainfall or industrial centers.

19. Interpret polar projection maps.

20. Make electric maps to match cities, states, waterways, or countries with their proper location.

21. Find current news items about countries being studied.

22. Make generalizations, prove or refute a point, substantiate a generalization from facts gained from social studies or science work.

23. Develop time lines to show sequences of events and relationship.

24. Chart events which occurred at the same time in different parts of the world.

25. Chart specific information about a subject to show relationships, such as causes of wars, reasons for population movements, and effects of inventions on industrial development.

26. Show relationships between current happenings and the past history of countries studied.

27. Determine implications of current happenings for future living, such as effect of drought on next year's food prices, of snowstorms on food supply, of forest fires on conservation.

One of the original science education programs built around the International Geophysical Year was successfully used last summer (in 1958) at the Florida State University elementary school:[7]

> "This was a natural development for two reasons: One, Florida schools have pioneered enrichment summer programs so that summers mean a continuation of school and not remedial work only. Two, with Florida providing the base for the launching of the U. S. earth satellite during IGY (Cape Canaveral), interest in the international program was natural and Florida educators quickly saw its potentialities for stimulating science education.
>
> "There was some hesitation when, at a teacher planning session late last winter, IGY was suggested for the 1957 science-centered summer school. At first, the term International Geophysical Year sounded too difficult for young children. However, when IGY was defined as a study of the earth — what is beneath the surface, on the surface, and above the surface — ideas for the science program came readily."

There have been many new science programs on educational TV which are pioneering steps in the right direction. The proponents of direct TV teaching point to the expanding enrollment in all of our schools, the shortages of teachers especially in the science field, and the lack of *qualified* instruction in science. TV, then, offers a practical means of affording the services of our best teachers to many hundreds and thousands of youth.

Surveys and studies point up the fact that a student gains as much (when measured by certain tests), if not more, from teaching through TV as from the conventional classroom method. There are those educators who envision television as that device which invites the "teaching elite" to perform on the screen and downgrades the average classroom teacher. It is true that teaching may become more mechanized and standardized if the teacher's role is reduced to glorified proctor.

The Major Work Classes in Cleveland, Ohio,[8] practice ability-grouping to provide for differences in abilities generally. The children in each Major Work area are drawn from several schools within travelling distance of the school in which the class is housed. Each class is an integral part of the school, and the gifted children are with other children during recess, in gym classes, in school assemblies, and in clubs. Thus segregation, but not isolation, is practiced. The gifted children master basic skills for the particular grade, and a wide variety of activities is organized around a central theme. Literature, science, creative experiences and excursions relative to the work engaged in are included in the program. There are similar types of classes for the gifted in Brockton and Malden, Massachusetts, where definite provision for individual differences are made and science interests are fostered and encouraged.

In The Colfax Plan (Pittsburgh, Pennsylvania), we find the premise being that grouping for learning is *advantageous for all groups*. Group-

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[7] *Elementary School Science Bulletin*, Produced by The Elementary Science Committee of the National Science Teachers Association, NEA, November 1957, p. 3.

[8] Theodore Hall, *Gifted Children, The Cleveland Story*, The World Publishing Co., New York, 1956.

ing in all subjects takes place, and half a day is spent by the superior children together, to execute (in groups) their ideas, to discuss and plan. Half of the day is devoted to this workshop where science ideas may be encouraged, reference books used, and problem-solutions explored. The other half of the day, these gifted pupils spend with their regular classes — their chronological mates.

The present writers believe that the subject matter of science is drawn from the most vital activities of our society. Dominant needs in our exciting era are discovered and problems solved. Answers are found in the gamut of problems from atomic energy to chemical farming. New medical discoveries are announced almost daily and the use of synthetics in the home as well as in industry is increasing. Our children are aware of these things as part of their immediate environment, and science-minded students are spontaneously interested in new developments from the *participation* point of view. These are the pupils, who, at any level of achievement, may be lost if the teacher does not use the opportunity for encouragement and special acknowledgment and guidance. Birch and McWilliams[9] offer the following suggestions for working with the gifted pupil:

> "Frequent, brief progress reports to the other pupils may encourage them to look for possibilities for independent research. Organizing his ideas to give a report helps to keep the pupil from getting lost; and if the teacher sets the stage properly, the report can add much to the prestige of the experimenter. This helps him to achieve status with his peers, for he is recognized as doing something worthwhile, but not so remote as to make him seem to be different from his classmates."

The same authors give the following as some other suggested projects for individual reports:

1. Construct science equipment.
2. Conduct experiments in animal breeding.
3. Test local rocks for mineral content.
4. Collect and classify: sea shells, fossils, butterflies, insects, leaves, rocks, flowers, grain samples.
5. Prepare experiments or demonstrations for class.
6. Serve as lab assistants to teacher.
7. Plan lesson and teach class when topic is one in which pupil is "at home."
8. Build models to illustrate structure or function of plants, animals or machines.
9. Build transportation models (rocket ships are very popular.)
10. Review scientific fiction critically for the class.
11. Teach microscope-technique to other pupils.
12. Keep scrapbook of clippings on recent developments in science.

[9] Jack W. Birch and Earl McWilliams, *Challenging Gifted Children*, Public School Publishing Co., Bloomington, Illinois, 1955, pp. 34–35.

13. Maintain clipping file to keep textbook data up-to-date.
14. Study history of science.
15. Read biographies of famous scientists.
16. Review new sample texts.
17. Use advanced texts up through college level, if able.
18. Prepare exhibit for science fair.

Group projects which are suggested by the authors are the following:

1. Set up a weather bureau.
2. Organize a seminar group with time to discuss or work on projects of their own choosing.
3. Prepare more complicated demonstrations for class presentation.
4. Collect animals and maintain a school zoo.
5. Plan and supervise the landscaping of the school grounds, and do the work if necessary.
6. Investigate soil erosion of the neighborhood and study suggested remedies.
7. Engage in study of conservation measures needed in area (water, forests, animals, fish, minerals).
8. Maintain science museum for use of entire school.
9. Collect and catalogue science pictures.
10. Investigate how the library can help in science research.
11. Take trips to museum, zoo, planetarium, science laboratory, manufacturing plant, fish hatchery, weather station, observatory, airport, railroad terminal, harbor, conservatory, agriculture experimental station, tannery, lumbermill, hospital, slaughter house, locks of river or canal, water purification plant, cannery.
12. Evaluate new sample texts.
13. Develop a science radio program or assembly program.
14. Conduct plant grafting experiments.
15. Make critical studies of the claims of advertisers.
16. Organize a science fair.

There are many other programs for the enrichment of the science life of the child of today. For example, in Oakland, California, a nature study class is offered at the Oakland Public Museum. It meets weekly throughout the entire year, the content being determined by the children's interests. The science areas are covered by discussion, informal lectures and craft work related to the subject. Of note are the various children's science programs offered in Massachusetts, from Worcester's museum groups to the Saturday classes offered by Boston's Science Park. Notable also are the other small groups which meet through the Massachusetts areas led by a science teacher or parent and subsidized completely by parents and interested adults.

Moon shots: The ascent of the *Sputniks*, the *Vanguards*, the *Pioneers* and the *Atlas 10B* have left their trails across the front pages of our newspapers. We have new "conversation pieces," it is true, but the problem that the present writers are wrestling with today is — should this launching of satellites and rockets affect the science programs in the schools of today, or is the elementary school teacher still to go on making leaf prints in October, studying birds in the Spring, and is the secondary school pupil still to be instructed to open his science text to page 49 and read to the end of the chapter? Our times are "teachable." Interest in science is high, and the unexplored beckons! If there is evidence that science teachers are more enthusiastic, that better science texts and trade books are being published, and that more attention is paid to problem-solving and investigating how children think, then we may be assured that science education has been revitalized and that the *Sputniks* have generated more knowledges and attitudes than was their primary intent. Today the cultural heritage of science should be transmitted to our children by stimulating true scientific curiosity and investigation.

Forecasting future events is risky but stimulating to the imagination. The writers would like to make the following predictions:

1. There will be an ever-increasing interest in elementary school science, with a definite tendency towards organization of structured programs.

2. There will be a greater *variety* of science books, both texts and trade books, in elementary and secondary classrooms, due to the fact that educators will realize that it is not necessary for one copy of the same science book to be in the hands of every child, but that many different books are rich sources of information.

3. Elementary school science will continue to be correlated with social studies, but there will be no forcing of the issue, and during the school year, a science unit or units will be studied for the sake of science alone, with natural correlation in the fields of the language arts, music, and the humanities.

4. There will be increased interest and participation in outdoor living and camping experiences in a contrived scientific environment for young and old pupils.

5. There will evolve new types of evaluations both in elementary and secondary science.

6. There will be more and more able science "specialists" to help those teachers with little or outdated science-training at all grade levels.

7. More time for science will be alloted in the whole school curriculum.

8. Grades 1–8 will have sequence of unitary approaches to all areas of science, with planned organization of ideas in a framework of principles. A reasonably flexible grade placement of these principles as unifying envelopes will insure that most children will finally be able to interpret the environment by sorting new experiences into sets described by the principles.

9. Grade 9 will begin the senior science sequence with biology. This will be strongly oriented toward human physiology and conservation — both having to do with man's ecological relationships.

10. In grades 10 and 11, and designed for *all* pupils, chemistry-general physical science will be available as a two-year block. It will be taught in a large laboratory (described above as a "barn"). This will not be formally mathematical. It will be patterned after the present and projected courses of The Physical Science Studies Committee.[10] This group plans to complete the physics materials by 1960, and then to start on chemistry. Earth science (with its own group of principles) will be increasingly available and challenging.

11. The final year of science will be elective. Some likely choices of science-minded students are: advanced-standing mathematical physics, earth science, advanced-standing chemistry, biology for nurses or pre-medics, astronomy, field work with community health agencies or in local industry, or with food-producing or handling agencies. Suitable mathematics prerequisites will need to have been met. The calculus will have been an adventure for the pure-science chemistry and physics students; statistics and simple accounting for the others. Part of *every* course will be a seminar where interdisciplinary skills, attitudes, and appreciations will be engendered.

12. High school students will increasingly be involved in the teaching process in science. There is no other drive so strong for many young people than to be recognized by their group as able and inventive. (It has long been possible for a high school student to demonstrate these traits in athletics, in editing of newspapers and yearbooks, in drama, and in political and social leadership.) In the seminar and in local or state science fairs, as travelling teacherettes, in national competitions for scholarships or awards, and on television there will be more and more opportunities for young adults to exhibit excellence in science.

13. There will be a whole new relationship, largely supported by federal funds, or in some measure by trade unions, among the teacher-training institutions, the schools, and some available science-minded college undergraduates who may or may not finally enter into teaching. If these young people in college have ability in science, they will become resource people in *science* for the public schools. That is, under the guidance of a teacher-training institution (part of or near a liberal arts college) science-able and science-minded college students will have assignments, as citizens, in nearby public schools to help teachers. Their contribution will be varied. They will bring with them demonstrations, reading materials in their own fields, apparatus which is returned to the college after use, and audio-visual aids. They will be able to talk about their own work in science, which may well be individual research. (Graduate science degree candidates are included in this plan.) They will be available as mentors for pupils with special interests in science. They will invite individual pupils back to the science laboratories of the college to see how science is taught there. They will take whole groups of elementary pupils on science field trips. If the rationale of this program seems confused, let it be remembered that many of the young men and women of college age will be parents. They will be teaching children whether or not they are engaged in the teaching profession.

[10] The Physical Science Study Committee, Massachusetts Institute of Technology, Cambridge, Massachusetts, *ibid.*

Programs in progress:[11]

> "NESDEC schools are using a variety of approaches to strengthen their science offerings. Warwick and Providence, R. I., are participating in an in-service institute in mathematics and science given by Brown University under a grant from the National Science Foundation. The purpose of the institute is to improve the subject matter competence of high school teachers through the resources of Brown University. Hampton, N. H., is enriching science courses through educational television programs. New Britain, Conn., has received an appropriation to purchase new science equipment which is four times larger than last year's. Milton, Massachusetts, introduced a unique science project last June. At the close of school each pupil, including prospective kindergarten children, was given a set of directions on making science collections. In September each classroom was assigned a different area of science for study and prepared a display based on the students' collections. Science is now a required subject in Medway in grade 7. Both Belmont and Concord, Mass., are giving biology courses to top freshmen in high school. Weston, Mass., offers a special course in grade 9, physical science, which consists of one-half year of physics and one-half year of chemistry. Lynnfield, in addition to teaching traditional science subjects in high school, offers courses in biological chemistry, advanced biology, chemistry, and physics. East Greenwich, R. I., gives a course in chemistry and one in physics in grade 12 which is comparable to a college course. In Springfield, Mass., fourteen students are enrolled in a program following the recommendations of the M.I.T. Physical Science Study Committee, which meets for two periods each day. In addition Springfield has another group of selected students who will complete a full year of biology in half a year, a full year of chemistry, and two and a half years of physics (through the P.S.S.C. program) prior to graduation."

There is another type of secondary school science program which may well be watched with interest. This is the integrated chemistry-physics course which has been taught at Phillips Exeter Academy in Exeter, New Hampshire, for many years. Since 1958 other local high schools have begun similar programs. Biology, in this type of program, is taught in the ninth grade. Science I and II, a fused chemistry-physics course, is taught every year. There are problems in this type of program, however, one large one being that some pupils need only chemistry for entrance into schools of nursing and similar colleges, and other pupils require the so-called college-preparatory physics for entrance into other schools.

These programs are those which are known to be going on in New England. Similar plans are being tried in other localities. Individual teachers as well as school systems are experimenting with action research — placing small inventions in science teaching under the scrutiny of analysis by

[11] *Nesdec News*, New England School Development Council, Spaulding House, 12:No. 2 (November 1958), Cambridge, Mass.

testing. It is to be hoped that these teachers will have their results published so others may replicate and refine their procedures as they prove to be successful.

From now on: Perhaps disagreement among educators, although an occupational disease, is a healthy sign. However, there is complete agreement all over our country that in America we do have many underdeveloped resources, among which is our great backlog of students from the primary grades through the college, waiting eagerly to be developed in the fields of scientific knowledges. We have an equal number of American adults who are sensitive to the educational problems of today and their possible solutions.

While there has been a new look at the status of science education because of the advent of the space age, there needs to be a look to the future from now on. That problem which presses hardest upon education today is not the production of more scientists. Neither is it the need for science education for everyone. The real problem is to make teachers and pupils in the schools of today aware of the unique and awesome path we are taking. Teachers and pupils go hand in hand along a road whose end they cannot see, whose sudden changes of direction are confusing, even frightening. Hopefully, hands are reached out to touch the fingers of historians, philosophers, statesmen, poets, engineers, writers — and mothers and fathers. The pattern of life has to be decided on now, by all of these. It is being etched by our homes, our churches, and our schools — but most of all by our schools. In the schools there are dedicated men and women; and children and young adults are truly as much the teachers' own as they are children of their full-time parents. Children must believe in teachers — parents must also believe in teachers. All teachers who teach the real world as part of man, hope that they will be able to meet this challenge; it is good that they *do* believe in themselves.

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